A Laboratory-Scale Bagel-Making Procedure[1]

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ABSTRACT

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A laboratory-scale baking process and scoring procedures were developed for bagels. The developed procedures had good reproducibility. Texture was evaluated using an Instron universal testing machine. The baking process was used to study the effects of formula ingredients and processing conditions. Retardation time, boiling time, flour protein level, salt levels, and water levels had effects on bagel volume and crumb scores. Flours and flour mixtures (with added gluten or starch) of differing qualities were used to bake bagels. They were evaluated for weight, volume, crumb score, and texture score. Significant differences occurred in volume and texture scores between flours.

A laboratory-scale procedure for baking bagels was developed by Meloan and Doerry (1988). This procedure used some elements of a general, commercial, bagel-making procedure. Applying these and other industry standards to a laboratory setting is an important step in developing a successful laboratory-scale baking test for flour quality. Any laboratory baking test must be sensitive to changes in ingredients and procedure. These changes result in differences in the quality of the batter or dough and in the final baked product that can be measured both objectively and subjectively.

There are essentially no reports in the scientific literature describing factors affecting bagel quality. The objectives of this study were to develop a sensitive laboratory-scale bagel-making procedure and to use that procedure to test the function of the formula ingredients, determine the importance of processing steps, and evaluate the suitability of various flours used for making bagels.

MATERIALS AND METHODS

Two commercial bagel flours (C and Y) were used as controls in this work (Table I). Mixograms for the two flours are shown in Figure 1. The two flours were from different sources and were presumed to represent commercial bagel flours. The bagels baked with these two flours were judged to be identical (Table II). Flours K, O, G, P, and W used in the flour-quality portion of this work were obtained from Kraft-General Foods (Chicago, IL), Domino's Pizza (Ann Arbor, MI), General Mills (Minneapolis, MN), Kansas State University (Manhattan, KS), Shawnee Milling Co. (Shawnee, OK), and Union Equity Co-op Exchange (Enid, OK). The flours K, O, G, P, and W and their attributes are listed in Table I and mixograms of these flours are shown in Figure 1.

Mixograph tests were executed according to standard method 54-40 (AACC 1983). Particle size distribution tests were performed using a Horiba particle size analyzer using 100% ethanol as a dispersant (Anonymous 1990b). Protein was determined by AACC method 46-10. The two-stage air-oven moisture procedure (AACC method 44-18) was used to determine bagel crumb moisture. Flour moisture was measured using AACC method 44-15A. The pH of dough was measured after adding 10 g of dough to 100 g of distilled water and blending thoroughly. Gassing tests were performed with a model 12 DSI gasograph over an 18-hr period using full dough formulations (flour Y). During the tests, the apparatus was placed in a cold room at ~2°C. Scanning electron micrographs (SEM) were obtained by cutting samples from one bagel from each group of four with the aid of a razor blade. Samples were mounted without prior drying on SEM stubs with carbon paste. They were sputter-coated with gold-palladium and then examined with an ETEC SEM. Accelerating voltage was 10 kV; the film was Polaroid type 55.

Bagel Formula

The other formula ingredients, on a flour weight basis, were 3.0% sugar, 2.0% salt, 0.8% dry yeast, and sufficient water to make a stiff dough. The appropriate water level for each flour was determined by optimizing the water level using a known formulation (Anonymous 1990a, Meloan and Doerry 1988) to make the dough from control flour, and then adding water to achieve that same consistency with the rest of the doughs.

Bagel Production Method

Dry ingredients and water were mixed for 7 min (or until just short of minimum mobility) in a mixer modified to mix at 32 rpm (100-200S TMCO, National Manufacturing, Lincoln, NE). The dough was removed from the mixer bowl, and four 70-g balls were formed from each dough. The balls were rolled using a modified sheeter-molder (National Manufacturing). The ends of two of the rollers were cut off to reduce the gap between them (Fig. 2). The distance between the rollers was 0.20 mm (measured by using a feeler gauge) when the top roller was fully depressed.

Cylinders of rolled dough 19.0 cm long and approximately 1.9 cm in diameter were coiled into a circle (Fig. 3). One end was wetted slightly with distilled water to aid in adhesion of the two ends. The formed bagels were placed on a baking sheet lined with silicon-treated paper (Bak-o-matic pan liners, James River Corp., Parchment, MI), covered with a polyethylene bag, and held (retarded) at ~2°C for 18 hr (Meloan and Doerry 1988). After retardation, the bagels were held at room temperature (23°C) for 15 min and then placed in a rapidly boiling water bath. They were boiled for 2 min, turned, and boiled for an additional 2 min. Variations in boiling time of 0, 1, 2, and 6 min total boiling time were also studied. The bagels were then placed on a rack to drain for as little time as feasible (no more than 30 sec) and placed on an expanded metal rack to bake. They were baked

TABLE I
Composition (%) and Properties of Flours

Flour	Moisture	Ash	Protein	Absorption	Mix Time (min)[a]
C (control 1)	13.7	0.53	14.0	60.0	3.0
Y (control 2)	12.66	0.52	14.2	63.0	3.0
K	13.9	0.43	13.6	60.0	4.0
O	13.7	0.44	10.3	55.0	5.2
P	14.9	0.49	13.4	60.5	3.4
G	13.1	0.53	14.4	56.5	2.6
W	12.6	0.53	9.8	57.0	4.5

[a]Based on mixograph optimum absorption and mix time.

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at 232°C for 13 min, cooled on a rack to room temperature, and then measured and scored.

Variation in Mixing Time

The mixing time variations studied were 4 min (enough mixing to give a cohesive mass) and 14 min (overmixing).

Retardation Time

Studies measured variations in retardation at 0, 1–5, and 10–36 hr.

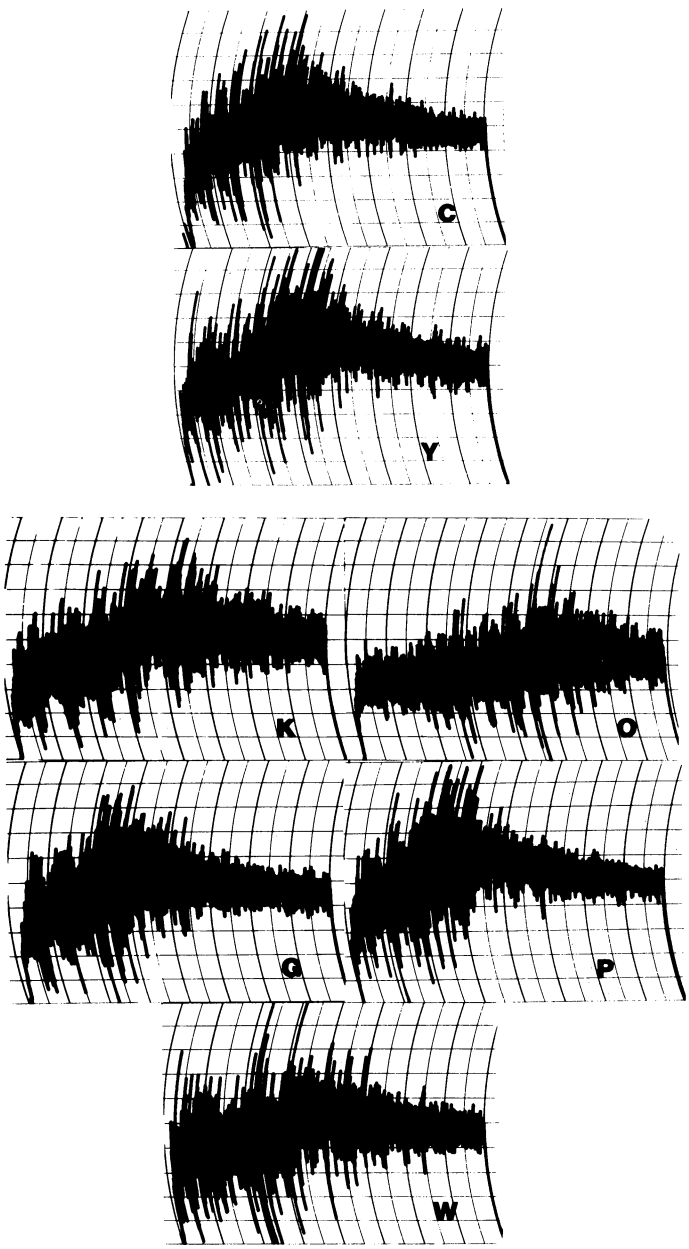

Fig. 1. Mixograms for commercial bagel flours C and Y and flours K, O, G, P, and W.

TABLE II
Volume and Crumb Score Measurements[a]

		Volume (cm³) by Season		
Flour	**Volume (cm³)**	**Low Humidity (5–25%)**	**High Humidity (50–75%)**	**Crumb Score**
C	143.54 ± 15.14 a	131.13 ± 12.77	151.50 ± 6.72	3.0 a
Y	144.18 ± 13.56 a	128.00 ± 10.54	158.25 ± 11.21	3.0 a

[a] Within columns, means followed by the same letter are not significantly different.

Reheating

In tests where the bagels were reheated to serving temperature, they were reheated in a microwave at high setting for 1 min (Sharp Carousel II), in a pastry toaster at medium setting (Toastmaster), or in a hot (232°C) reel oven (National Manufacturing).

Variation in Protein

To examine the effect of flour protein in bagel making, two different methods of altering protein content were examined. In the first method, a control flour was either supplemented with vital wheat gluten to raise the protein level by 2% or diluted with starch to lower the protein level by 2%. The flour mixtures were then made into bagels and compared to a bagel made from an unaltered flour. The second method used flours of differing protein content and quality. Bagels were then baked and scored for weight, volume, crumb score, and texture.

Formula Variation

Water levels were varied by adding or subtracting 2.5 or 4% from the optimum water level. Standard granulation sucrose was

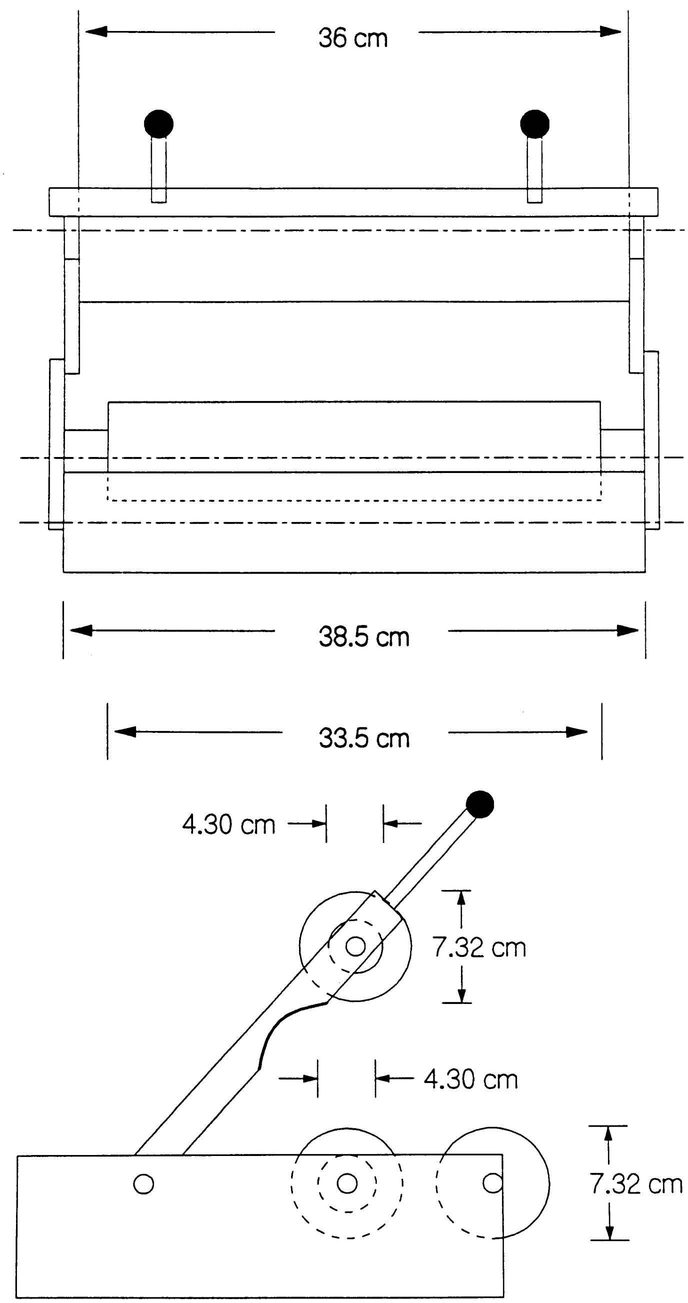

Fig. 2. Diagrams of modified sheeter-molder equipment (top) front angle view and side view.

used as sugar (Holly Sugar, Colorado Springs, CO). Salt levels tested were 0, 1, 1.6, 1.8, 2, 2.2, 2.4, 3, and 4% on a flour weight basis. The standard formula contained 0.8% dry yeast (Fermipan, Gist-Brocades Co., King of Prussia, PA); variations of 0.4, 1.2, and 1.6% were also studied. Compressed yeast (Red Star, Milwaukee, WI) was used at a level (2.4%) equivalent to that of the dry yeast. Glycine was from Sigma Chemical (St. Louis, MO). In certain experiments, $KBrO_3$ was added at levels of 10 and 20 ppm.

Protein Quality

The flours mentioned above were either fortified with vital wheat gluten or diluted with starch to adjust the protein level of each flour to that of the standard flour protein (14.2%).

Scoring Procedures

The bagel volume measurements were made using pup-loaf-size rapeseed displacement equipment (National Manufacturing). Two bagels from each batch of four were analyzed for texture, and two were analyzed for crumb score.

The bagels were weighed, cut at their equator, and evaluated subjectively for crumb score using a scale of 1–5. A score of 1 reflects a bagel with fine, tight cells. A score of 5 reflects a bagel with thick cell walls and an open structure more like that of an English muffin. A score of 3 (medium coarse grain and medium open structure) was chosen as optimum.

Mechanical texture was evaluated with an Instron universal testing machine (UTM). The bagels were cut into 2.2-cm cubes, without crust, using the crumb area directly opposite the seam. Cubes were always placed on the testing platform with the face nearest the baking surface facing up. A 50-kg load cell was used on the UTM with a chart speed of 10 cm/min and a crosshead speed of 5 cm/min. The crosshead carried a cylindrical metal rod 1.3 cm in diameter, beveled to a flat end of 1.2 cm, which was used to compress the center of the cubes to 18.75, 37.5, and 75% of their original height. Each cube was compressed twice in succession to mimic biting.

A triangle sensory evaluation was performed by students with sensory analysis training. Each evaluator was presented a three-sectioned plate with three labeled bagel pieces, including two pieces from the same bagel variation and one piece from a different variation. The evaluators were asked to pick the bagel piece that was different.

RESULTS AND DISCUSSION

Procedure

Each batch of four bagels baked from one dough was scored as a unit to simplify the statistics. The bagels baked with the control flours weighed 60.66 ± 0.51 g and had a volume of 144 ± 15.14 cm^3. Volume varied with seasonal humidity in the laboratory (Table II). Aside from seasonal variations, this procedure produced bagels from the two commercial bagel flours that were not statistically different in terms of volume and crumb score (Table II) over a two-year period.

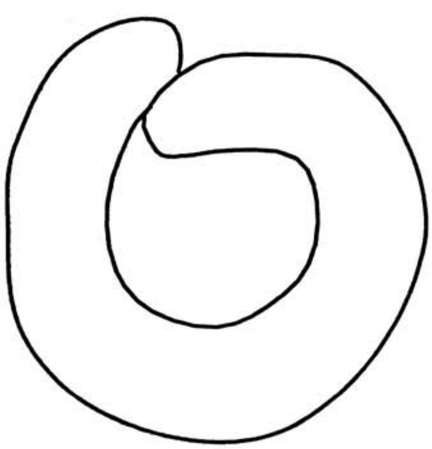

Fig. 3. Diagram of bagel dough after forming.

This effect on volume was seen through two years of changing seasons and was attributed to the fact that bagel dough is low in moisture and requires a large amount of manipulation (mixing and forming) before retardation. Also, the surface-to-crumb ratio is large, which allows more water to evaporate. To minimize this problem, the dough was kept in plastic bags or covered with plastic during handling. Also, dough water was increased (2%) during the dry months of the year to help compensate for water lost by evaporation during handling.

Boiling the bagel dough after retardation is the classic procedure in bagel-making operations. Today, many large-scale manufacturers use steam-injected ovens to achieve a similar effect (Petrofsky 1986). During the boiling step, the dough expands because of increased levels of gas production and expansion of the gas present in the dough. The bagels increase in size and thereby decrease in specific gravity; they will float shortly after being placed in the boiling water. Also during boiling, the outer crust is set by partial gelatinization of the starch present (Umbach et al 1990). When the bagels were boiled too long, they expanded too much and then collapsed. They did not reexpand during baking. When the bagels were not boiled long enough, expansion was insufficient, and the crumb scores and volumes were low. There was a window of time in the water bath of between 90 and 180 sec per side that produced bagels of similar crumb score and volume.

In this study, bagels were taken individually from the water bath and placed on the rack to drain, then all four bagels were immediately transferred to the baking rack and placed in the oven. Minimal time was allowed for draining because of a tendency of the bagels to irreversibly collapse before baking. The process of removing the bagels from the water bath, draining them, and placing them in the oven took an average of 45 sec. It appeared that the boiling time and the time that the bagel could tolerate

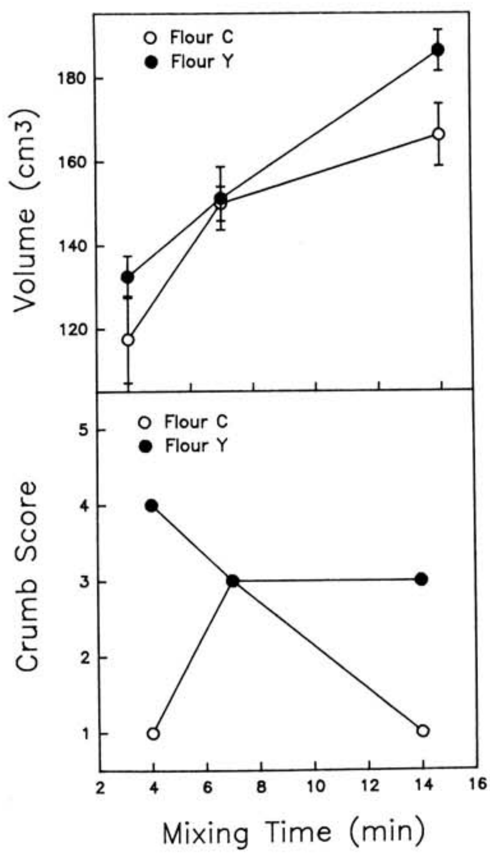

Fig. 4. Effect of mixing time on bagel volume and crumb score of commercial bagel flours C and Y.

before collapsing were related. The longer the bagels were boiled, the more susceptible they were to collapse.

Effect of Mix Time

The stiff doughs were slightly undermixed. A standard mix time of 7 min was chosen for the control flours. Variations of mix time were tested for their effect on the volume and crumb scores of the bagels (Fig. 4). The two standard flours C and Y were mixed for 4, 7, and 14 min. A mix time of 4 min was just enough to attain cohesion of ingredients. The bagels made with doughs from both flours with a short mix time had low volumes (~120 cm^3) and had thick cell walls with a dense, nonuniform grain. Bagels made from flour C with a long mix time (14 min) had high volumes (165 cm^3) but low crumb scores. Flour Y had a greater tolerance to overmixing. Bagels made from that flour with the long mix time (14 min) had high volume (185 cm^3) and desirable crumb grain. Mixing tolerance of the flour prepared with optimum water, as shown by mixograms (Fig. 1), appeared to correlate well with the mixing tolerance of the actual bagel dough.

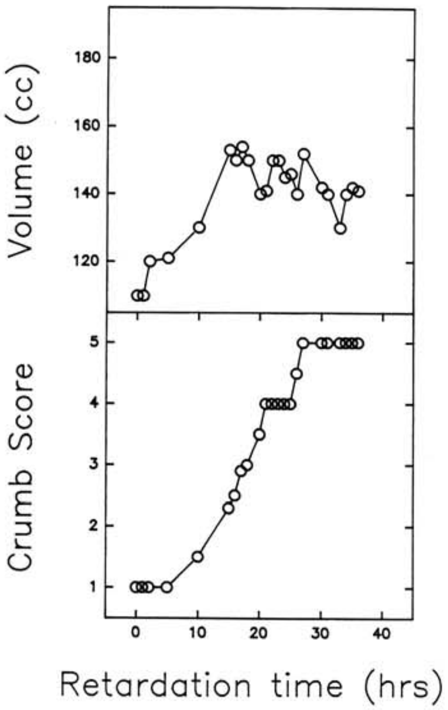

Fig. 5. Effect of retardation time on volume and crumb score of flour Y.

Effect of Retardation

Retardation time had several important effects on the properties of bagels. Retardation times of <16 hr, produced bagels with low volume and crumb grain scores (Fig. 5). The crusts of those bagels were pale in color, and the texture lacked the chewy-tough characteristics of a traditional bagel (Fig. 6). In an attempt to induce more of the foxy red-brown color seen in standard bagels, glycine was added at the 0.2% level. This induced additional browning, but the color was still not the same as that of the bagels with longer retardation times. Bagels with higher volumes and better crumb scores were produced with retardation times of 16–20 hr, in contrast to those produced with short retardation times (Fig. 5). Their crust developed the foxy red-brown color characteristic of the control bagel. In addition, the bagel surface had small, pinpoint blisters (Fig. 6). After 20 hr of retardation, the bagel crust was darker and had many unacceptable, large (fish-eye) blisters. These bagels also had an open, English muffin-like, crumb structure. Longer retardation times (>20 hr) resulted in bagels with volumes not significantly different than those of the control (18-hr retardation).

Freshly mixed bagel dough had a pH of 6. This did not change during the retardation time (18 hr). The average gas production of the doughs during 18 hr in the gasograph was 14.14 ± 1.2 gasograph units (GU), which is equivalent to 33.65 ± 2.86 cm^3 CO_2.

Reheating

Reheating bagels before consuming is a common practice. When the bagels were reheated using methods that heat the surface rapidly, such as a toaster or a microwave oven, blisters were formed on the surface (Fig. 7). As variations in bagel ingredients and processing were tested and scored, those bagels were also reheated and examined for blisters. The most obvious difference in blistering quality was a function of retardation time. Bagels made with no retardation (Fig. 8) do not blister when reheated. As retardation time increased to >17 hr, the bagels showed marked blistering during reheating. These blisters differed from the fish-eye blister found on bagels with excessively long retardation time (>20 hr) (Fig. 6). The blisters caused by heating were protruding, large, expanded air cells.

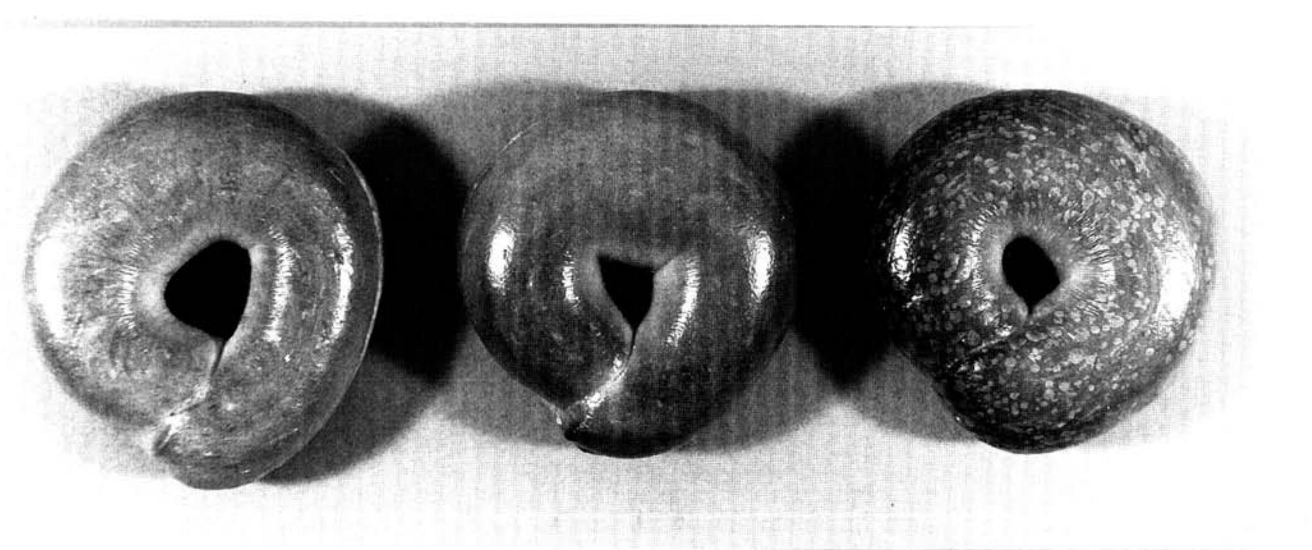

Fig. 6. Samples showing effect of retardation time on crust color and bubbles: low retardation (left), control (center), and >30 hr of retardation (right).

When examined with SEM, the crust of the unheated retarded bagel showed a thick, collapsed section at the surface that contained no visible air cells (Fig. 7). Crust sections of unretarded bagels did not show this section (Fig. 8), but had a thin, bread-like crust. During retardation, the gas in the cells at or near the surface diffuses to the surrounding atmosphere, leaving only very small cells. These cells do not reexpand during the boiling and baking processes. However, during rapid reheating (toasting or microwaving), the small cells rapidly expand and form the blisters (Fig. 7).

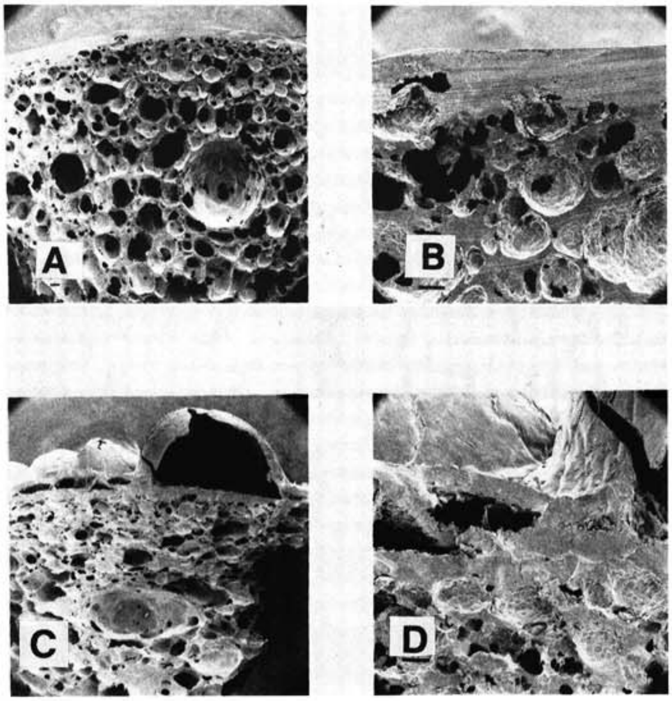

Fig. 7. Crust cross sections from scanning electron microscopy of baked bagels previously retarded 18 hr (**A** and **B**) and reheated bagels previously retarded 18 hr (**C** and **D**). Bar = 100 μm.

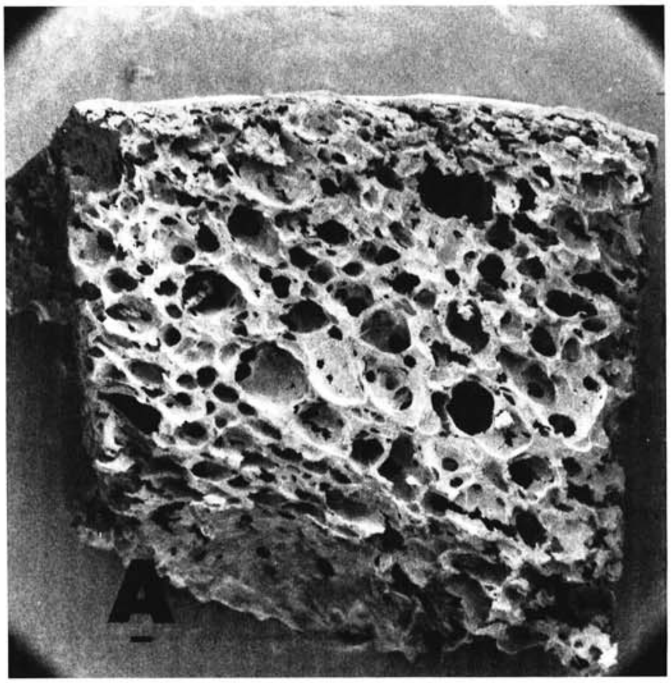

Fig. 8. Crust cross section from scanning electron microscopy of baked but previously unretarded bagel. Bar = 100 μm.

Effect of Protein

The bagels made from flour mixtures with 2% higher protein than that of the control showed significant improvement in volume and significantly different crumb structure from that of the control (Table III). The bagels made from flour mixtures with 2% lower protein also showed significant differences in crumb structure, but not in volume, when compared to the standard. This test was replicated with both standard flours with similar results (Table III).

Potassium bromate was added to determine its possible improving action. The levels used were those that show improvement in bread. The levels of 10 and 20 ppm gave no improvement in crumb score or bagel volume.

Effect of Water

Bagels have a relatively low water content when compared to many other breads and rolls. Published bagel formulations (Petrofsky 1986, Meloan and Doerry 1988) had water levels of 50–55% on a flour weight basis. Small variations in water levels (±2.5%) caused insignificant changes in both volume and crumb score but did have an effect on dough-handling properties. The drier doughs were stiff and tended to dry on the surface during handling. Wetter doughs were more extensible, and the surface did not dry.

Effect of Salt

Salt (NaCl) is one of the vital ingredients of bread (Hoseney 1986). Salt is also important for bagel making. Attempts to make bagels without salt produced doughs that were slack and sticky. Small variations (±0.2%) caused no significant variation in bagel quality. Larger changes in the salt levels were examined for the effects on bagel volume, crumb score, and dough-handling properties. The standard level of salt used in this work was 2%, on a flour weight basis. Salt level affected volume, crumb scores, and dough handling. At salt levels of 1%, the dough was slack and extensible. The bagels had a open crumb and high volume. At >3% salt, the dough was stiff and difficult to work. Those bagels had low volumes and poor crumb scores.

Effect of Yeast

Instant dry yeast levels in standard bagels were 0.8% on a flour weight basis. Bagels made with 0.4% yeast had low volume and a poor crumb score. Bagels made with 1.2 and 1.6% yeast had open grains and high volumes. The bagels made with 1.6% yeast gave large bubbles during boiling and often collapsed afterwards. Bagels made with an equivalent amount of compressed yeast had volumes and crumb scores virtually identical to those of bagels made with instant dry yeast.

Flour Quality

Bagels baked from the original flours (not corrected to 14.2% protein) showed differences in both crumb score and volume (Table IV).

Flours K, O, P, G, and W (adjusted to 14.2% protein) gave baked bagels with similar crumb scores. The bagels made with flour G were significantly lower in volume than those from the other flours, except for control flour Y. Flour K produced bagels that were similar in volume to those from the control flour. The rest of the flours (O, P, and W) produced bagels with volumes

TABLE III
Effects of Flour Protein Level on Bagel Volume and Crumb Score[a]

Flour	Protein Level (%)	Volume	Crumb Score
C	12	141.25 c	2.0 b
C	14	143.54 c	3.0 c
C	16	191.67 a	4.0 a
Y	12.2	137.50 c	2.0 b
Y	14.2	144.18 c	3.0 c
Y	16.2	175.00 b	4.0 a

[a]Within columns, means followed by the same letters are not significantly different.

TABLE IV
Changes in Mean Volume and Crumb Score with Changes in Flour[a,b]

Flour	Protein	Volume (cm^3)	Crumb Score[c]	Volume (cm^3)[d]
Control (Y)	14.2	127.70 a	3.0 a	127.7 de
K	13.9	127.50 a	2.0 b	132.5 cd
O	13.7	108.75 b	2.0 b	141.9 ab
P	14.9	128.30 a	3.0 a	135.9 bc
G	13.1	133.75 a	3.0 a	120.8 e
W	12.6	113.75 b	2.0 b	147.3 a

[a] As is protein levels and optimum absorption.
[b] Within the same column, means followed by the same letter are not significantly different.
[c] Scale of 1–5 (3 = optimum).
[d] Flour protein of samples adjusted to 14.0 by adding gluten or starch. Mean weight of bagels (61.1) and crumb scores (3) were not significantly different.

TABLE V
Force (kg) Required to Deform Bagel Cube[a]

	Compression of Total Height (%)					
	18.75		37.5		75	
Flour	1st	2nd	1st	2nd	1st	2nd
Control	0.54 a	0.19 a	0.80 a	0.38 ab	2.2 a	1.81 a
K	0.47 ab	0.15 ab	0.77 a	0.31 a–c	2.3 a	1.89 a
O	0.53 a	0.15 ab	0.83 a	0.32 a–c	2.2 a	1.92 a
P	0.33 c	0.12 b	0.53 b	0.26 bc	1.5 b	1.30 b
G	0.51 a	0.19 a	0.84 a	0.44 a	2.1 a	1.79 a
W	0.37 bc	0.12 b	0.57 b	0.24 c	1.6 b	1.37 b

[a] Within the same columns, means followed by the same letter are not significantly different.

that were significantly higher than those of the control. The average volume of the control bagels were lower than the statistical mean volume for the whole study. This was because this portion of the study was performed as a unit during a low humidity time of the year.

One of the most obvious differences in the flours tested was observed during the dough-handling process, and can be analyzed only qualitatively. The dough made from flour O was stiff and rather elastic. Dough made from flour K was bucky. Dough made from flours P and G behaved in a similar fashion to that of the standard. Dough made from flour W required a substantial addition of gluten to adjust the protein level and, therefore, required more water and mixing. The dough from this flour was stiff.

Flours P and W produced bagels that required significantly lower force for 75% deformation of the bagel cube (Table V). They also required lower force at 25 and 50% deformation. Bagels from one of these flours (W) were used in a triangle test against bagels produced from the standard flour to determine whether the mechanically measured differences in firmness were detectable by a sensory panel. They were not.

CONCLUSIONS

The procedures outlined in this article proved to be useful in making and evaluating bagels in a laboratory setting. The developed procedure had good reproducibility. During boiling, the bagels decreased in specific gravity. When boiled too long, they became susceptible to irreversible collapse. Adequate mixing of the dough was required to obtain good volume. The two control flours used varied widely in tolerance to overmixing.

Retardation of bagels for at least 16 hr appeared to be necessary to avoid bagels with pale color and to obtain bagels with the chewy-tough characteristic of a traditional bagel. Too long of a retardation time (>20 hr) produced large, undesirable, fish-eye blisters. In addition, an optimum retardation time was necessary to obtain blistering during reheating. This was considered desirable. Examination by SEM showed that adequately retarded bagels had a thick crust formed during retardation. This crust was not formed in bagels with a short retardation time. Addition of gluten (2%) to bagel flours increased their volume.

Among the formula ingredients, water, salt, and yeast affected bagel quality. Flours that varied in protein content and quality gave bagels that varied in quality. Addition of gluten or starch to make all the flours contain 14.2% protein reduced the variation but did not eliminate it.

Two flours produced bagels that required lower force to deform the bagel with a UTM. This result was not confirmed by a sensory panel.

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